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BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF HILLS BEACH BIDDEFORD MAINE

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS.

JULY 27, 1961

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF HILLS BEACH, BIDDEFORD, MAINE

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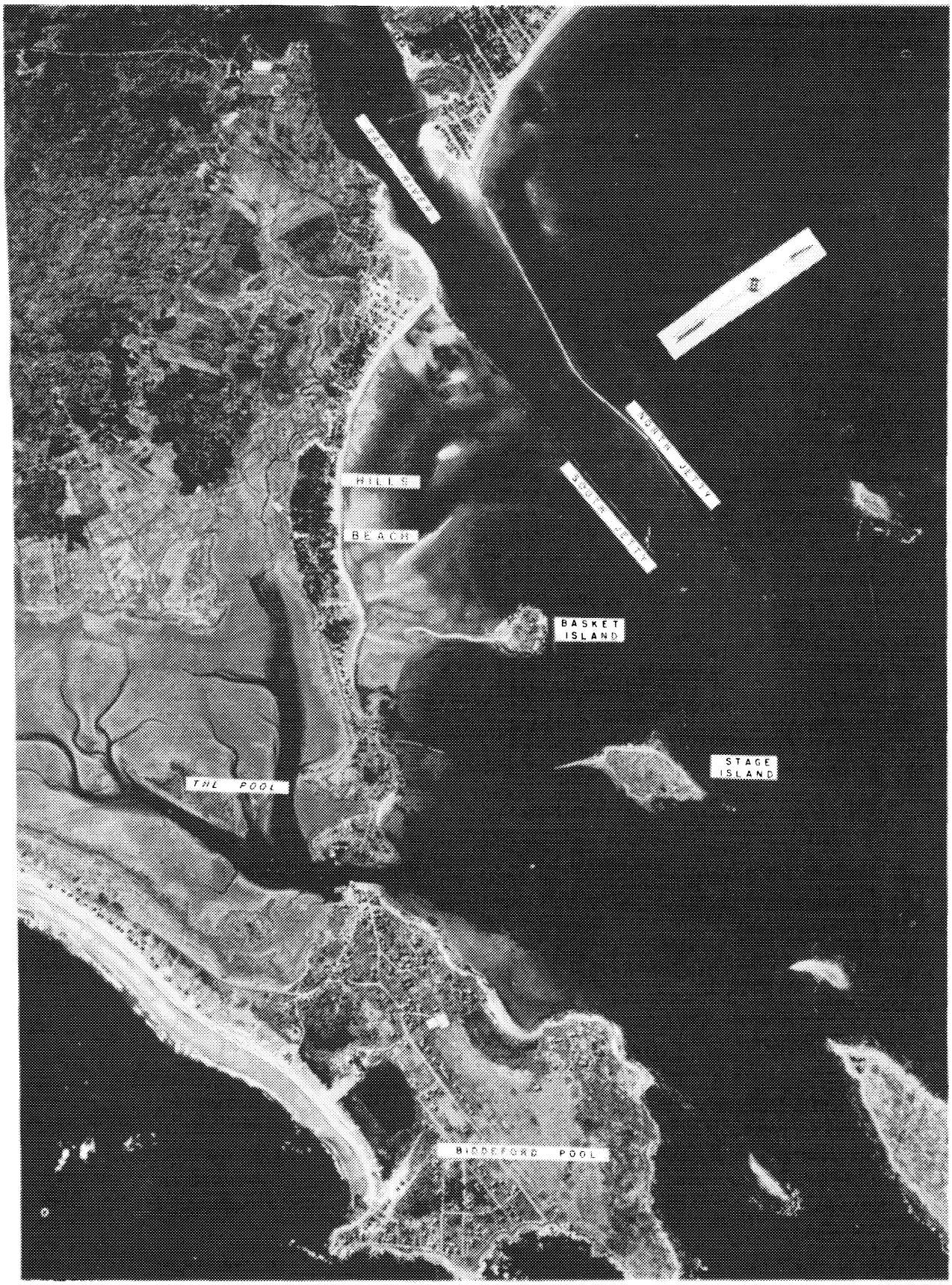


Photo 1. Hills Beach, Biddeford. April 29, 1954. Tide 1.8 feet above mean low water.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM 54, MASS.

NEDGW

27 July 1961

SUBJECT: Beach Erosion Control Report on Cooperative Study of Hills Beach, Biddeford, Maine

TO: Chief of Engineers
Department of the Army
Washington 25, D. C.

SYLLABUS

The purpose of the study is to determine the best method of restoration of protective and recreational beaches and protection of shore property.

The Division Engineer finds that erosion has resulted in loss of sandy beach and exposure of bluffs, sea walls, shore road, cottages and residences to damages from wave attack during storms. He also finds that due to the private ownership of the shore and the lack of public benefits as required by Public Law 826, 84th Congress, Hills Beach is not eligible for Federal assistance in the construction of protective works.

The Division Engineer has developed a practicable method for protecting and restoring 5,400 feet of Hills Beach adjacent to the Saco River South Jetty consisting of widening the beach by direct placement of sand fill and raising the inshore end of the jetty. He has also developed alternative methods of protection consisting of construction of riprap revetments.

The Division Engineer recommends that no project be adopted by the United States and that protective measures which may be undertaken by local interests based upon their determination of economic justification be accomplished in accordance with plans and methods considered in his report.

BEACH EROSION CONTROL REPORT ON

COOPERATIVE STUDY OF HILLS BEACH, BIDDEFORD, MAINE

PART I - GENERAL

1. Authority. - This study was made by the Corps of Engineers, United States Army in cooperation with the City of Biddeford, Maine under authority of Section 2 of the River and Harbor Act approved 3 July 1930 as amended and supplemented. The formal application for the study dated 13 December 1958 was approved by the Chief of Engineers on 16 January 1959.

2. Purpose. The purpose of the study is to determine the best method of restoration of protective and recreational beaches and protection of shore property.

3. Prior Reports. There has been no prior report on beach erosion control for Hills Beach. A cooperative beach erosion control study of the shore of the adjacent City of Saco has been made. The report on this study submitted by the Division Engineer, New England Division on 5 October 1955, was printed in House Document No. 32, 85th Congress, 1st Session. It was concerned primarily with erosion of the Saco shore but it contains general information about factors pertinent to erosion of Hills Beach. Numerous preliminary examination and survey reports for navigation improvements of Saco River and the Pool at Biddeford, Wood Island Harbor, located adjacent to Hills Beach, have also been made.

4. Description. Hills Beach is located in York County, Biddeford, Maine at the south end of Saco Bay. It is adjacent to and extends about 7,500 feet southeastward from the south jetty at the Saco River entrance to the entrance of The Pool at Biddeford. The east end of the beach borders Wood Island Harbor, an offshore body of water sheltered by a small group of islands. A sandy shore borders Saco Bay north of the Saco River along Camp Ellis, Ferry Beach, Bay View, Kinney Shores, Ocean Park, Old Orchard Beach and Pine Point. The location is shown on United States Coast and Geodetic Survey Chart Nos. 231 and 1205, on United States Geologic Survey topographic Quadrangles for Biddeford and Biddeford Pool, on Plate No. 1 and on Photos 1 to 7.

5. The centers of the cities of Biddeford and Saco are located on opposite sides of the Saco River about 4 miles upstream from Hills Beach. They are served by the Boston and Maine Railroad. In 1960

they had populations of 19,255 and 10,515 respectively. The cities constitute the largest industrial, commercial, banking, shopping and service trade center in York County serving the large summer resort areas of Wells, Kennebunk, Kennebunkport and Old Orchard Beach.

6. Hills Beach is privately owned and occupied by about 200 summer cottages and year round residences. It is accessible over State highways and local roads. Hills Beach Road runs through the entire length of Hills Beach and is closely bordered on both sides by the beach development. The beach is a sandy barrier bar varying from 200 to 1,000 feet in width. There are marshes behind the northerly half of the beach and an almost completely enclosed body of water known as The Pool behind the southerly half. The south end of the beach is characterized by outcrops of bedrock both on and offshore. Sanitary tests of shore water made during 1946 showed a B. coli count of up to 50 per milliliter indicating that pollution does occur.

7. Statement of the Problem and Improvements Desired. The problem consists of erosion and loss of the sandy beach and consequent exposure of cottages and residences bordering the shore to damages from wave attack during storms. Serious and costly damages have occurred to sea walls and bulkheads. Local interests want to determine the cause of erosion and the best methods for preventing it. They feel that erosion is associated with the condition of the south jetty at the Saco River entrance. They claim that the erosion has occurred following subsidence of the jetty and they desire to have this structure repaired and raised. There have been no public hearings. Meetings and inspection were held on 27 February 1958, 29 April 1958 and 26 January 1960 before and during conduct of the study. They were attended by representatives of the Beach Erosion Board and the Division Engineer, a State senator, the Mayor of Biddeford, city officials and officers and members of the Hills Beach Association.

PART II - FACTORS PERTINENT TO THE PROBLEM

8. Geomorphology. Hills Beach, situated on the southern headland enclosing Saco Bay, comprises the north arm of a wave-built, partially bedrock controlled double, or cuspate, tombolo which projects eastward from the mainland south of the Saco River mouth to a volcanic and granitic island thinly veneered with glacial till. The island, Biddeford Pool, lies almost 2 miles from the rock mainland

Photo 2. Hills Beach, Biddeford. February 28, 1961. Erosion along northwest end of beach. Saco River jetties in background.

Photo 3. Hills Beach, Biddeford. February 28, 1961. Eroded bluff along northwesterly end of beach.

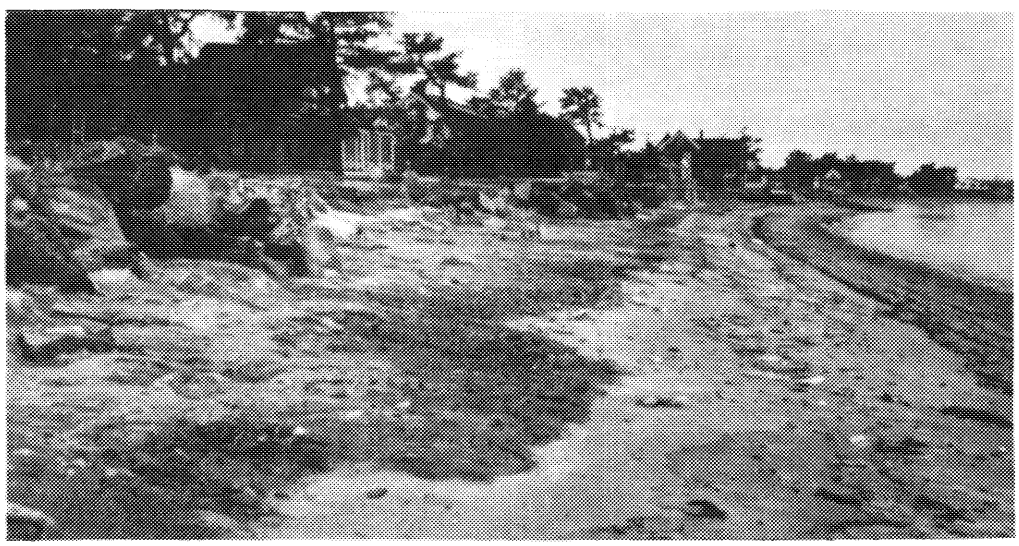


Photo 4. Hills Beach, Biddeford. February 28, 1961. Riprap and low walls along central portion of beach.

Photo 5. Hills Beach, Biddeford. February 28, 1961. Northwest from Basket Island tombolo.

Photo 6. Hills Beach, Biddeford. February 28, 1961. Riprap and timber bulkheads protect low road and cottages along shore opposite Stage and Basket Islands.

Photo 7. Hills Beach, Biddeford. February 28, 1961. Riprap and timber bulkheads protect low road and cottages at rocky east end of beach.

and is the largest of several islands which appear to owe their existence above sea level to the predominance in their composition of volcanic rocks which are resistant to erosion. The attitudes of the rock beds directly control the shape of Biddeford Pool. Anticlinal close folding, crushing, and faulting of the west end of the island resulted in a depression in the rock which admits the sea into "The Pool" or lagoon enclosed by the tombolo arms.

9. The seaward end of Hills Beach terminates on the smaller outlying segment of rock west of the structural breach. The land end of Hills Beach terminates on bedrock forming the southern edge of the Saco River mouth. The Saco River south jetty anchors the beach a bit seaward of exposed bedrock and, taken in conjunction with the river's strong tidal flow and a higher jetty north of the river mouth, provides a barrier to littoral drift from the north. The original sources of sand for the Old Orchard Beach barrier beach of which Hills Beach may be regarded as the extreme southern extension are of historical importance only. Old Orchard and Ocean Park Beaches lie roughly between Biddeford Pool and Prouts Neck, the latter a cuspate tombolo connecting to a large rock island which forms the northern headland of Saco Bay. The stretch between Prouts Neck and the Biddeford Pool tombolos is an offshore bar fronting marshy drainage areas both north and south of a rock controlled hill which, at Old Orchard, tangentially approaches the offshore beach bar. Thick sand terraces which flank this hill may have supplied large quantities of the sand comprising the original 6-mile long beach bar. Heavy erosion of former mantle on both Prouts Neck and Biddeford Pool headlands, plus the erosion of former islands within Saco Bay also must have contributed significantly to the original materials of the bar. The Saco Bay area in effect, at present, is well-confined probably neither losing nor gaining much material past the headlands. A considerable retarding effect at Hills Beach exists, however, in that the beach is held by rock anchors at both ends between which the effective inroad of wave action is considerably diminished because refractive damping involving a substantial loss of energy is required for wave access. Considerable protection against inshore progression of nearshore bottom contours is afforded by the relatively resistant rock, till and gravel islands just offshore.

10. Littoral Materials. The character of littoral materials was determined by mechanical analysis of beach and nearshore samples obtained on Profiles 3, 6 and 9. The results are shown in tabular form in Appendix A. Materials consisted principally of fine and medium sands. Finest samples were obtained on Profile 9 and coarsest samples on Profile 6. Average median diameters were 0.41, 0.90 and

0.31 mm on Profiles 3, 6 and 9 respectively. Glacial materials have constituted the principal source of beach materials. Erosion of these deposits and their transportation by littoral currents as littoral drift has contributed to the formation of the beaches. There are no evident sources other than the existing beaches which now contribute any appreciable amount of material to littoral drift. The character of nearshore material was investigated by means of probings. The locations and results are shown on Plate 3. Probings indicate that sand overlies rock in the nearshore area.

11. Littoral Forces.

a. Waves. - Waves approach the shore of Hills Beach from the northeast to east across the Atlantic Ocean and the Gulf of Maine. The jetties at the Saco River entrance provide shelter from waves from the north. A group of small islands partially shelter the shore from waves from the northeast to east. The shore lies in the lee of the mainland and of Fletchers Neck located to the west and south. The fetch across the Gulf of Maine to the northeast is limited to approximately 200 miles by Nova Scotia. The fetch across the Atlantic Ocean to the east is not limited. No wave measurements are available. A hindcast wave study based on synoptic weather charts for locations off Penobscot Bay, Maine and Nauset Beach, Cape Cod, Massachusetts has been made by the Beach Erosion Board. Wave roses based on data from the study are shown on Plate 1. They indicate that waves of the greatest duration and height occur from the east northeast and east.

b. Currents. - Tidal currents along the coast flood to the north and ebb to the south. Tidal currents flood into and ebb out of the Saco River and The Pool through Saco Bay and Wood Island Harbor. Additional information on currents is included in Appendix C.

c. Winds. - Records of the United States Weather Bureau at Portland, Maine for the ten-year period October 1949 to September 1959 show that the prevailing winds blow offshore from westerly directions and the duration of onshore winds is longer from the northeast than from the southeast quadrant. A wind diagram based on the above observations is shown on Plate 1. A tabulated summary of the observations and more detailed descriptions are included in Appendix B.

d. Storms. - Records compiled from the United States Weather Bureau at Boston for the 75-year period 1870-1945, inclusive, show that there has been a high preponderance of northeast storms. The storms were major disturbances often of several days duration accompanied by rain or snow, high tides, shore inundation, battering of sea walls by wave attack, washing and blowing of debris and sand onto coastal roads and damages to low-lying shore developments. Detailed storm wind records are shown in Appendix B.

e. Tides. - The tides at Hills Beach are semidurnal. The mean range at Wood Island Harbor, adjacent to the beach, is 8.7 feet and the Spring range is 9.9 feet. Tide records at Portland, Maine show that on an average tides exceed the plane of mean high water approximately as follows: by 1 foot or more 116 times per year; by 2 feet or more 19 times per year; by 3 feet or more once a year. The maximum tide height of 4.3 feet above mean high water was observed at Portland on 30 November 1944 and 20 November 1945. Detailed information is included in Appendix C.

12. Shore History. - a. Shoreline and Offshore Changes. - Shoreline and offshore depth charges are shown on Plate 2. Changes during the period of record have varied alternately between accretion and recession. The amounts of changes determined from surveys of 1859, 1871, 1913, 1954 and 1960 are tabulated below: Changes from other surveys are also included on Plate 2.

High Water Shoreline Changes (1859-1960)

Period	Shore Location (Measured from inshore end of South Jetty)	Change
1859-1871	600' to 1200' North	Accretion 0-50'
	600' North to 2500' South	Recession 0-150'
	2,500' to 2700' South	Accretion 0-300'
1871-1913	800' North to 2500' South	Accretion 0-350'
	2,500' to 4200' South	Recession 0-100'
1913-1954	350' to 1000' North	Erosion 0-200'
	350' North to 400' South	Accretion 0-120'
	400' to 3200' South	Erosion 0-100'
	3,200' to 4100' South	Accretion 0-200'
1954-1960	200' to 800' North	Accretion 0-200'
	200' North to 4600' South	Erosion 0-100'

The large amount of accretion between 1871 and 1913 is attributable to impounding of material by the south jetty following initiation of its construction in 1891. The net result of shoreline changes from 1913 to 1960 consisted predominantly of recession with some accretion at or north of the south jetty. The net result of all shoreline changes from 1871 to 1960 consisted of accretion of about 400 feet at the south jetty and along approximately 400 feet of shore north of it. This accretion decreased gradually along 1,200 feet of shore south from the jetty. From 1,200 to 3,800 feet south of the jetty shore line changes consisted of recession generally of 50 to 75 feet.

Offshore depth changes between 1875 and 1923 consisted generally of shoaling and seaward movement of the 12 and 18-foot depth contours while in the vicinity of the 6-foot depth, changes consisted irregularly of deepening and shoaling. The principal deepening occurred in the location of Profile 7. The survey indicates that additional deepening occurred since 1923 in the location of Profiles 6 and 7.

b. Prior Corrective Action and Existing Structures. - Protective structures have been built by private property owners in front of cottages and low sandy bluffs located close to the shore. They consist of timber bulkheads, rubble masonry, concrete and dry stone walls and riprap revetment. Structures are discontinuous, protecting individual properties or small groups of properties. Riprap revetment and dry stone walls have been used for protection of short segments of Hills Beach Road along the east end of the beach. A long stone jetty constructed by the United States as part of a navigation improvement exists at the west end of the beach at the mouth of the Saco River. This jetty was built from 1892 to 1912 to a length of 5,100 feet. The authorized Federal project provided for a top elevation of 5.5 feet above mean low water, top width of 10 feet and side slopes of 1 on 1. A more detailed description of this jetty and of another parallel structure at the north side of the Saco River mouth is included in Appendix D. Due to erosion of the fronting sand beach many of the structures fronting private properties have been exposed to wave attack and some are in a state of disrepair. The Saco River south jetty resulted in considerable accretion after its construction. It is presently in a deteriorated condition due to settlement and displacement of stones and therefore not very effective as a barrier to littoral drift.

c. Profiles. - Profiles were surveyed at selected locations as shown on Plate 3. Plots of the profiles are included on Plates 4 and 5. Beach slopes in the vicinity of and above mean high water vary from 1 vertical on 3 horizontal to 1 on 17 with the most common slope 1 on 9 to 1 on 10. Between mean high and mean low water slopes vary from 1 on 12 to 1 on 43. Below low water profiles are generally level.

PART III - ANALYSIS OF THE PROBLEM

13. Shore Processes Pertinent to the Problem. - The loss of beach material and damages to shore structures are caused by wave action. Waves approach the shore from the northeast to east and are refracted and diffracted around sheltering jetties, islands, shoals and headlands resulting in a diverse movement of littoral drift.

Northward movement of littoral drift along the north end of the beach is evidenced by the large amount of accretion which has occurred in the vicinity of the jetty and the adjacent shore of the river mouth north of it. Movement of material between Basket and Stage Islands and Hills Beach is shown by the existing submarine tombolos. The cuspate form of the beach at the inshore end of the Basket Island tombolo indicates alongshore movement of material towards this point from both directions. The extensive offshore shoals are evidence of offshore movement of material. Material also moves landward particularly over low narrow portions of the southerly end of the beach. There are no apparent external sources of supply furnishing material to the beach. The rate of loss exceeds the rate of supply resulting in recession of the shore line and exposure of the existing development to wave attack. The most rapid erosion and severest damages are attributed to northeast storms and storms accompanied by extreme high tides. Under present conditions it is probable that erosion and recession of the shore will continue and the shore development will become more exposed to damages.

14. Methods of Correcting Problem Conditions. - The rate of supply of beach material can be increased artificially by placing sand directly on the beach. Probings indicate that there is a supply of sand in the area directly offshore within a practicable distance for placement along the beach by the hydraulic dredging process. Suitable material also exists in The Pool landward of the beach and in the Saco River entrance. Widening of the beach in this manner would provide a large measure of protection against wave attack. Reduction of losses of beach material from the problem area can be effected by construction of barriers to its alongshore and landward movement. Loss of beach material now transported alongshore toward the river mouth can be reduced by raising the inshore end of the existing jetty. This would result in a reduction of the rate of supply of material to the shore of the river mouth north of the jetty, a beach which has gained 400 feet in width since 1871 as a result of erosion and transport of material from Hills Beach to the south. This accretion would cease and possibly change to erosion, in which event construction of protective works might be required for protection of the recent residential development in the area. Loss of material landward over low sections of the beach and shore at and east of the east end of the beach widening (see Plate 6) can be reduced by raising the road. Armoring the shore against wave attack by construction of seawalls, bulkheads, or revetments is an effective method of protecting eroding bluffs, low sections of the shore road and the cottage development. This latter method would not contribute to the creation of a fronting beach but it could be used as an alternative to or to supplement the protection that would be provided by placement of sandfill. Shore areas in locations where it is not practicable to place or hold a fronting sand beach can be protected with riprap revetment.

15. Design Criteria. - Proposed protective measures are designed to provide protection against ordinary conditions of comparatively frequent occurrence (at least once a year). They are not intended to provide complete protection in the event of hurricanes or exceptional storms of infrequent occurrence although even under these conditions considerable protection will be afforded. The design of structures is described in detail in Appendix E, Design Analysis.

a. Design Tide. - The design tide is the maximum expected to occur once each year. The elevation of the design tide is 11.7 feet above mean low water.

b. Design Wave. - The maximum height of the design wave was determined from the relationship d/H=1.28 where d is the depth of breaking and H is the height of wave at breaking using the depth at or in front of the proposed structure at time of design tide as the depth of breaking. The height of the wave selected for design of the proposed structure was modified based on experience and judgment taking into account the sheltering effect of islands, shoals and jetties and the probable effects of refraction, diffraction and the obliquity of approach of waves. The wave height selected for design of the jetty was 7.0 feet and for the revetment was 2.4 feet.

c. Sizes and Slopes of Stones in Structures. - Sizes and slopes of cap and slope armor stones for jetty or revetment construction are computed using the United States Army Waterways Experiment Station formula. Sizes of stones in the underlying bedding and filter layers were based on successive 1/10th and 1/200th reductions of the weight of the armor stone.

d. Jetty. - The horizontal shore section should ordinarily have a top elevation not lower than the general height of the berm of the existing beach and a length not less than the berm width of the anticipated beach. Experience indicates that the top elevation of the jetty intended to block passage of sand should be 16.0 feet above mean low water.

e. Sand Fill. - The berm elevation of the proposed beach fill is based on that at existing beaches. The minimum width of the fill between the high water line and shore structures is based on the width found to afford protection in the area. Estimated volumes of fills are based on slopes similar to existing slopes but fills can be placed initially to a steeper slope and permitted to take a natural slope under wave action. Based on these criteria the berm elevation is approximately 15 feet above mean low water, the beach width above mean high water in front of protective structures is generally 125

feet and fill slopes are 1 on 10 to 1 on 30. Suitable sand for beach fills would have size and gradation characteristics similar to those of existing beach materials. For the purpose of detailed design of the beach fill, the investigation of materials on the beach and in the proposed borrow areas should be supplemented when plans and specifications are being prepared.

PART IV - PLAN OF PROTECTION

16. Plan of Protection. - A plan of protection and restoration has been developed for approximately 5,400 feet of beach adjacent to and extending southeastward from the existing south jetty at the Saco River entrance. The plan consists of raising the inshore end of the south jetty at the Saco River entrance by increasing its height and making it sand tight to prevent loss of beach material by northward drifting into the river mouth and widening the beach generally to a 125-foot width between the high water line and the protective structures fronting the existing development. The fill would protect the development against wave attack, by dissipation of wave energy. Probings indicate that suitable material for fill exists in the nearshore area of Wood Island Harbor. Past dredging records indicate that suitable material exists in Biddeford Pool. Sandy material also exists at the Saco River entrance. Consideration was given to raising both the inshore 330 feet and the inshore 530 feet of the jetty to a top elevation of 16.0 feet, with the top thence sloping seaward on a 1 on 10 slope to mean high water and then on a 1 on 30 slope to its intersection with the existing jetty. The shorter length would provide just enough impounding capacity to retain the fill proposed to be placed directly adjacent to it and would therefore permit passage of any drifting material over its top into the river mouth. Raising 550 feet would provide a 200-foot length of impounding capacity which could hold drifting material for a number of years. Material so impounded could be used as a source of borrow for replenishing the beach as it becomes necessary, thereby renewing the impounding capacity of the structure. Raising the longer section of jetty, dependent upon renewal of its impounding capacity, would be much more effective in reducing losses of material into the river mouth than the shorter one, the reductions of losses estimated as approximately 20,000 and 5,000 cubic yards per year, respectively. In view of the much larger, prevention of loss of material, raising the longer section of jetty appears warranted even though it might eventually result in erosion of the adjacent shore of the river mouth and the need for construction of works for the protection of the residential development in this area. The plan for raising 550 feet of the inshore end of the jetty, which with its sloping outer section involves reconstruction of 700 feet of jetty, was therefore selected and is shown on Plate 6. Supplemental protection in addition to the fill, can be provided, if experience indicates the need,

by construction of sea walls, bulkheads or revetments. An alternative method of protection, instead of the beach widening and jetty raising consisting of stone revetment has also been considered. Typical sections showing details of suitable types of revetments are shown on Plate 6. The shore southeast of the proposed fill area where placement of beach fill is unsuitable due to probable high losses can also be protected with stone revetment placed along the toe of existing timber bulkheads or along the seaward side of Hills Beach Road. Protection against overtopping can be provided along low road sections by filling and reconstruction of the road at a higher elevation and protection of the embankment with riprap revetment.

17. Estimates of Cost. - The first cost of the beach fill is based on use of the hydraulic dredging process. First costs and annual charges are based on price levels prevailing during May 1961. An economic life of 50 years is used in determining amortization charges. An interest rate of 3.5 percent has been used for annual charges which are all non-Federal. The annual maintenance requirement for beach fill is based on the shoreline recession which occurred during the period 1954-1960 when it is estimated that beach losses averaged 6 cubic yards per linear foot per year. It is assumed that the proposed jetty raising will prevent losses along 1,500 feet adjacent to the structure and will reduce the rate of loss about 50 percent along the rest of the shore. Estimates of first costs and annual charges have been made for the entire plan involving beach widening and raising the inshore end of the jetty. Estimates of first costs have also been made for a one-foot length of the alternative typical stone revetment for seawall protection and for a one-foot length of the alternative typical stone revetment for bluff protection. Estimates are as follows:

a. Entire Beach Widening and Jetty Raising Plan.

First Costs	
Sandfill, 290,000 cu yds @ $1.30	$433,500*
Jetty reconstruction, 9000 tons stone @ $7.50	76,500*
Subtotal	510,000*
Engineering and Design	15,000
Subtotal	525,000
Supervision and Administration	35,000
Total First Cost	$560,000*
Annual Charges	
Interest (.035 x 560,000)	19,600
Amortization (.00763 x 560,000)	4,300
Maintenance	
Groin and jetty, 90 tons stone @ $10.00	900
Sand fill, 11,000 cu yds @ $1.50	16,500
Total Annual Charges	$ 41,300

* Includes Contingencies

Alternative Plan

b. One-Foot Length of Stone Revetment for Seawall Protection

First Costs	
Armor stone, 1 ton @ $7.50	$ 8.50*
Bedding stone, 1.6 tons @ $6.00	11.00*
Filter stone, 0.8 tons @ $4.50	4.50*
Excavation, 1.7 cu yds @ $1.00	2.00*
Subtotal	26.00*
Engineering and Design	1.00
Subtotal	27.00
Supervision and Administration	2.00
Total First Cost	$ 29.00*

* Includes Contingencies

Alternative Plan

c. One-Foot Length of Stone Revetment for Bluff Protection

First Costs	
Armor stone, 1.6 tons @ $7.50	$ 14.00*
Bedding stone, 2.6 tons @ $6.00	18.00*
Filter stone, 1.6 tons @ $4.50	8.00*
Excavation, 2 cu yds @ $1.00	2.20*
Subtotal	$ 42.20*
Engineering and Design	1.30
Subtotal	$ 43.50
Supervision and Administration	3.50
Total First Cost	$ 47.00*

* Includes Contingencies

18. Benefits. - Benefits have not been evaluated for the proposed project since the benefits to be derived are principally private and not of a type to make the project eligible for Federal aid under existing Federal policy. Private benefits consist of prevention of direct damages which now occur as erosion of beach and backshore area, and damages to shore structures and buildings. Private benefits would also result by increase of the earning power or value of shore land. The proposed raising of the inshore end of the south jetty would also result in a public benefit by impounding sand which now drifts into the Saco River entrance and contributes to shoaling of the Federal navigation channel. Due to the limited amount of navigation and the shallow draft of vessels using the channel, little maintenance is required. The benefit to be derived from reduction of the shoaling is therefore small. It consists of a part of $3,000, the presently estimated annual maintenance cost of the entire Federal navigation project, of which the entrance channel is but a small part.

19. Apportionment of Cost. - Public Law 826, 84th Congress, established a policy of Federal aid for restoration and protection against erosion of the shores of the United States, its Territories and possessions. In accordance with this policy, private shores are eligible for Federal assistance if there is a benefit such as that arising from public use or from the protection of nearby public property or if the benefits to those shores are incidental to the project. The study area consists of privately owned shores, improvement of which would not result in significant public benefits. All estimated costs are therefore apportioned as non-Federal costs.

20. Coordination with Other Agencies. - Coordination has been maintained with the cooperating agency, the City of Biddeford, through the Mayor. Officials and members of the Hills Beach Association have been consulted. The Mayor was invited to furnish comments on the findings of the study. The views of the Federal and State fish and wildlife agencies have been requested concerning aspects of the study pertaining to their interests.

21. Comments of Local Interests and Other Agencies. - The Maine Department of Sea and Shore Fisheries advised that an investigation discloses no adverse effect on the fishing interests. The United States Fish and Wildlife Service submitted a report prepared in cooperation with the Maine Department of Inland Fisheries, Sea and Shore Fisheries and the Bureau of Commercial Fisheries. The report attributed important wildlife values to the large triangular offshore area formed by the Saco River South jetty, Hills Beach and Stage Island associated with its use as a feeding habitat for waterfowl. "The Pool" behind Hills Beach also receives some waterfowl use but this is not a significantly important area. The mouth of the Saco River is not important from a waterfowl standpoint. In view of the above the United States Fish and Wildlife Service recommended

a. That no beach fill be obtained from the off-beach area lying between Hills Beach and the south jetty.

b. That the mouth of the Saco River be given first consideration as a source of beach fill and that The Pool be given second consideration.

The complete report of the United States Fish and Wildlife Service is included in Appendix F.

22. At a meeting held at Biddeford, Maine on 31 May 1961, the Mayor of Biddeford and a number of officials and residents of Hills Beach expressed strong dissatisfaction with the findings of the study. Local interests desired Federal assistance for the construction of protective works. The deterioration of the south Saco River jetty was blamed for the erosion of Hills Beach and local people felt that the Federal government was responsible and should therefore repair and raise the jetty. Written comments were requested from the cooperating agency but none were furnished.

PART V - CONCLUSIONS AND RECOMMENDATIONS

23. Conclusions. - The Division Engineer concludes that widening approximately 5,400 feet of beach adjacent to and southeast of the existing Saco River south jetty to a 125-foot width by direct placement of sand fill, and raising 700 feet of the inshore end of the jetty, all as shown on Plate 6, is a practicable method for protecting and restoring Hills Beach. Supplemental protection within the fill area can be provided, if needed, by construction of sea walls, bulkheads or revetments in front of buildings or roads.

24. An alternative method of protection for individual properties instead of the beach widening and jetty raising, consists of construction of stone revetments in front of existing sea walls or bluffs. Details of typical revetments are shown on Plate 6.

25. Protection against overtopping of the shore road in low areas can be provided by reconstructing the road on an embankment and protecting the embankment with riprap revetment.

26. The shore, southeast of the fill area can be protected by placement of riprap revetment along the toe of bulkheads or along the edge of the shore road.

27. Due to the private ownership of the shore and the lack of public benefits as required by Public Law 826, 84th Congress, Hills Beach is not eligible for Federal assistance in the construction of protective works.

28. It is probable that the high cost of construction of adequate protective works may be a deterrent to their construction by local interests. It may be possible for the United States to provide some assistance for protection of Hills Beach in connection

with future maintenance of the existing Federal navigation projects at Saco River and the Pool at Biddeford by disposal along the shore of the beach of sandy material dredged from the channels. Maintenance of the Saco River entrance channel by making the south jetty sand tight or raising its inshore end, should navigational use require it, would also serve to protect the beach.

29. Additional information on recommended and alternative projects called for by Resolution 148, 85th Congress, 1st Session adopted 28 January 1958 is contained in Appendix G to this report.

30. Recommendations. - It is recommended that no project be adopted by the United States for the protection of the shore of Hills Beach, Biddeford, Maine. It is further recommended that protective measures which may be undertaken by local interests, based upon their determination of economic justification be accomplished in accordance with plans and methods considered in this report.

Incl
7 Appendices
6 Plates

SEYMOUR A. POTTER, JR.
Brigadier General, USA
Division Engineer

APPENDIX A

SAMPLES OF BEACH AND NEARSHORE MATERIAL

Samples of surface beach and nearshore material were obtained on Profiles 3, 6 and 9. Locations of profiles are shown on Plate 1. Underwater samples were obtained with a small clamshell bucket known as a Petterson dredge. Samples were obtained from the dune, berm, mid-tide, low water and 6-foot depth zones of the beach and nearshore area. A mechanical analysis was made of each sample and the results are included in the following tables. Information tabulated includes cumulative weight percentages retained on the various sieves and median diameters for each sample and for the averages of all samples on each profile. Sorting and skewness coefficients are also listed for individual samples. Information on samples of beach and nearshore material at Saco Beach was obtained during a prior beach erosion control study of Saco Beach and it has been printed in House Document No. 32, 85th Congress, 1st Session.

Sieve Analysis

U.S. Standard Sieve No.	1"	3/4"	1/2"	3/8"	1/4"	4	8	10	20	40	70	80	100	200	PAN	Median Diam. mm	Sorting Coefficient	Skewness Coefficient
Diameter in mm	25.4	19.10	12.70	9.52	6.35	4.76	2.38	2.00	0.84	0.42	0.210	0.177	0.149	0.074				
Locations	Cumulative Weight Percentage Retained																	
							Profile #3											
Dune								0.0	0.6	54.4	98.8		99.7	100	100	0.45	1.31	0.74
Berm								0.0	1.3	62.4	99.4		100	100	100	0.45	1.14	1.03
Mid Tide							0.0	0.6	3.2	23.6	76.7		95.2	98.4	100	0.26	1.41	1.30
Low Water							0.0	1.2	22.3	54.5	66.8		79.7	94.9	100	0.47	2.37	0.60
Totals							0.0	1.8	27.4	194.9	341.7		374.6	393.3				
Average							0.0	0.5	7.0	48.7	85.4		93.7	98.3	100	0.41		
							Profile #6											
Dune	0.0	8.2	23.3	30.9	* 37.0	42.2		54.1	63.4	77.8	89.8	* 92.0	92.3	95.1	100	2.6	5.10	0.78
Berm						0.0		2.4	9.1	64.9	98.8	99.5	100	100	100	0.48	1.19	1.13
Mid Tide						0.0		0.7	1.4	39.4	95.7	97.5	99.0	99.7	100	0.39	1.17	1.00
Low Water								0.0	3.3	37.9	65.3	75.0	88.8	99.2	100	0.28	1.87	1.30
6' Depth						0.0		2.2	42.4	97.8	99.6	99.9	100	100	100	0.74	1.04	1.17
Totals	0.0	8.2	23.3	30.9	37.0	42.2		59.4	119.6	317.8	449.2	463.9	480.1	494.0	500.0	4.49		
Average	0.0	1.7	4.7	6.3	7.5	8.5		12.0	24.2	64.3	90.9	93.9	97.2	100	100	0.90		
							Profile #9											
Dune								0.0	0.4	37.4	97.4		99.6	100	100	0.35	1.39	1.04
Berm					*				0.0	11.1	91.1		99.2	99.7	100	0.26	1.23	1.11
Mid Tide			0.0	0.9	1.4	1.8		4.2	13.5	34.7	82.0		96.7	99.4	100	0.31	1.50	1.27
Totals			0.0	0.9	1.4	1.8		4.2	13.9	83.2	270.5		295.5	299.1	300	0.92		
Average			0.0	0.30	0.47	0.60		1.4	4.6	27.8	90.4		98.8	100	100	0.31		

NOTE: * Estimated

APPENDIX B

PREVAILING WINDS AND STORMS

1. Prevailing Winds. - United States Weather Bureau records are available from the weather station at Portland, Maine approximately 16 miles north of the study area. A wind diagram was prepared based on hourly observations of wind speed and direction and it is shown on Plate 1. It shows a high preponderance of duration for westerly winds and the longest duration from the west direction and the northwest quadrant. Winds from all easterly directions which generate waves which affect the study area occurred about one-third of the time. The duration of easterly winds was greatest from the north notheast direction and the northeast quadrant.

2. Storm Winds. - A summary of the number of storms compiled from records of the United States Weather Bureau at Boston, Massachusetts, covering the 75-year period 1870-1945, inclusive, is given in the following table.

Storms (1870-1945, inclusive)

Direction	N	NE	E	SE	S	SW	W	NW	Total
No. of storms	3	80	9	14	12	15	13	14	160
Percent of total	2	50	6	9	7	9	8	9	100

The above storms represent major disturbances accompanied by high wind speeds of long duration. Classification of direction of each storm was made in accordance with the predominant direction of wind. Variations in direction during storms are not accounted for. From the above, it is apparent that there has been a high preponderance of severe northeast storms.

3. A tabulation showing the duration of winds, their direction and speeds compiled from United States Weather Bureau records for Portland is shown below.

Wind Speeds and Directions (October 1949 - September 1959 Inclusive)

Portland, Maine

Number of Hours

Wind Speed M.P.H.	0-3	4-7	8-12	13-18	19-24	25-31	32-38	39-46	47 & Over	Total
Direction										
N	441	2,341	2,788	1,745	383	74	31	4	-	7,807
NNE	240	1,006	1,570	1,409	361	88	6	3	-	4,785
NE	148	723	860	486	143	47	4	-	-	2,411
ENE	118	639	849	573	141	86	31	2	-	2,439
E	159	801	1,233	802	177	77	27	10	4	3,290
ESE	159	689	849	459	78	22	4	-	-	2,256
SE	157	646	537	296	50	16	5	3	-	1,700
SSE	175	763	1,234	873	138	74	29	9	1	3,296
S	320	1,596	2,543	2,197	378	83	5	1	-	7,123
SSW	356	2,130	2,486	1,265	150	22	-	-	-	6,405
SW	457	2,402	2,096	799	73	15	2	-	-	5,844
WSW	528	2,650	2,254	1,300	319	96	11	1	-	7,159
W	754	3,271	2,282	1,225	340	124	11	-	1	8,007
WNW	663	2,924	2,176	1,152	300	68	5	-	-	7,388
NW	631	2,659	2,036	1,309	257	51	5	1	-	6,949
NNW	462	2,053	2,021	1,522	281	43	2	-	-	6,384

Winds of gale force (39 miles per hour or higher) occurred predominantly from easterly directions with the predominance greater from the east direction and the southeast quadrant, while winds of lesser intensity predominantly blow offshore from the westerly directions.

APPENDIX C

TIDES AND CURRENTS

1. Tides. - The tides are semidiurnal. The mean and spring tidal ranges at Wood Island Harbor are 8.7 and 9.9 feet respectively. The highest estimated tide in this location was 13.5 feet above mean low water and the highest observed tide at Portland Harbor was 13.2 feet. A comparison of 65 high waters observed at Biddeford Pool was made with corresponding high waters at Portland, Maine. The comparison showed that variations from mean heights were the same at both locations 27 times, and they differed by 0.1 foot 19 times, by 0.2 foot 14 times and by 0.3 feet 5 times. This close agreement indicates that variations from the mean at Portland are similar to those in the study area. The frequencies of occurence of tides which exceeded the mean height by 1 foot or more was determined from continuous tidal observations for the 19 year period 1912 through 1930 at Portland, Maine and they are shown in the following table.

Frequency of Occurence of Tides Exceeding
Mean High Water at Portland, Maine (1912-1930)

Feet in Excess of M.H.W.	Average Annual Number of Occurrences*	Feet in Excess of M.H.W.	Average Annual Number of Occurrences
3.6	.05	2.2	11.3
3.5	.1	2.1	14.6
3.4	.3	2.0	18.5
3.3	.3	1.9	24.7
3.2	.4	1.8	29.8
3.1	.7	1.7	36.8
3.0	1.0	1.6	43.6
2.9	1.3	1.5	51.8
2.8	1.5	1.4	61.1
2.7	2.1	1.3	72.9
2.6	2.8	1.2	85.2
2.5	4.1	1.1	100.0
2.4	5.7	1.0	116.0
2.3	8.4		

* Average number of times the tide equalled or exceeded the given height.

2. Currents. - Maximum tidal currents along the Maine coast flood in a northerly direction and ebb in a southerly direction. The average velocity of these maximum currents are 0.3 knot according to "Tidal Current Tables, 1961, Atlantic Coast of North America" issued by the United States Coast and Geodetic Survey. No information is available concerning tidal currents at Hills Beach. Tidal currents flood in a southwestward direction into the Biddeford Pool inlet at the south end of Hills Beach and ebb in a northeastward direction. Tidal currents flood in a westward direction and ebb in an eastward direction at the Saco River inlet at the north end of Hills Beach. During the higher stages of each tide, currents flow over the top of the Saco River south jetty. Inlet tidal currents may have some effect on the movement of littoral material along Hills Beach but the principal movement of material results from littoral currents generated by breaking waves.

APPENDIX D

SACO RIVER JETTIES

1. Two stone jetties have been constructed at the mouth of the Saco River for maintenance and improvement of the navigation channel. The jetties were authorized by the River and Harbor Acts of 1866, 1890, 1910, 1925 and 1935. The north jetty, described as the breakwater in the navigation project, was begun in June 1867 and was completed to a length of 2,550 feet with a top elevation of about 9 feet above mean low water on July 1868. The jetty was extended to a length of 4,000 feet by October 1868 and to 4,200 feet by November 1869 but with less than the full height and thickness. Construction was continued completing the jetty to its full cross section in June 1873. Work was commenced on May 1885 on raising the top elevation of the jetty from 9 to 15 feet above mean low water. Work was done from the seaward end towards the shore completing the outer 510 feet by September 1885, the outer 710 feet by June 1887, the outer 1,310 feet by October 1887, the outer 2,100 feet by June 1890, the outer 2,320 feet by June 1891, the outer 3,480 feet by November 1895 and the entire 4,200 feet by December 1897. The north jetty was repaired in 1912 and a riprap spur dike about 400 feet long was built extending northward from it generally parallel to and about 50 to 100 feet seaward of the high water shore line. The spur was constructed to protect against flanking of the inner end of the north jetty during storms. The elevations of the top of the spur ranged from 8.6 feet above mean low water at the north jetty to about 3.0 feet at its outer end. The north jetty was extended seaward 1,600 feet from 1928 to 1930 and an additional 830 feet from 1937 to 1938, both extensions to a top elevation of 5.5 feet completing the jetty to its present length of approximately 5,800 feet. The inner 4,200 feet of the north jetty was built to a top width of 12 feet, a side slope of 1.7 to 1 on its north side and 1 on 1 on the river side. The 1930 and 1938 seaward extensions were built with top widths of 10 and 8 feet, respectively, and side slopes on both the north and river sides of 1 on 1.

2. Repairs were completed to the inshore end of the north jetty in June 1958 connecting it to high ground to impound littoral drift for protection of the adjoining beach in accordance with recommendations in the cooperative beach erosion control report on Saco, Maine, dated 5 October 1955 printed in House Document No, 32, 85th Congress, 1st Session. Visual inspection of the area since the 1958 repairs indicates that beach material has been impounded by the jetty.

3. Construction of the south jetty was started in April 1891 and it was worked on during each following fiscal year to June 1894 extending it by stages to a length of 4,500 feet. Low places were repaired in 1895 and 1900. A 600 foot seaward extension was added during 1911 and 1912 completing the jetty to its present length of 5,100 feet. Repairs were made to beacons and the jetty in 1912, 1913, 1928, 1930 and 1931. The authorized Federal project provided for a top elevation of 5.5 feet, top width of 10 feet and side slopes of 1 on 1. Biddeford residents claim that the south jetty was built higher to above high water and that due to its subsidence, erosion of Hills Beach has occurred. Records of as-built conditions are not available to show the exact heights after completion of construction.

APPENDIX E

DESIGN ANALYSIS

1. General. The raising of the inshore end of the south jetty and the riprap revetment were designed for the maximum wave height expected to occur at the site using a tide elevation which occurs on an average once a year. The design wave height was computed using the solitary wave formula $d/H = 1.28$ where d is the depth of water at breaking and H is the wave height. The computed wave height for the jetty was modified based on experience and judgment to take into account the sheltering effect of islands, shoals and jetties and the probable effects of refraction, diffraction and the obliquity of wave approach. Sizes and slopes of armor stones were computed using the United States Army Waterways Experiment Station Formula

$$Wr = \frac{\gamma_r H^3}{K_\Delta (Sr-1)^3 \cot \alpha}$$

where
- Wr is the weight of armor stone
- γ_r is the specific weight of armor stone in pounds per cubic foot
- K_Δ is a dimensionless experimental coefficient
- H is the design wave height
- Sr is the specific gravity of the armor unit relative to the water in which the structure is located equal to γ_r/γ_w where γ_w is the specific weight of the water in pounds per cubic foot
- α is the angle of the breakwater slope

2. Design Wave. The design tide is 11.7 feet above mean low water. The bottom elevation at the jetty is 1.5 feet above mean low water. Assuming breaking at the structure, the depth of breaking, d, is therefore 10.2 feet.

$$\text{From } \frac{d}{H} = 1.28$$

$$\text{the maximum wave height } H = \frac{10.2}{1.28} = 7.97 \text{ feet}$$

A smaller wave height, 7.0 feet, was selected for design purposes since some reduction in wave height occurs at this site from sheltering effects, wave refraction, diffraction and obliquity of wave approach. Breaking of waves attacking the riprap revetment was assumed to occur in the vicinity of the high water line in a

water depth of 3 feet at time of design tide. Therefore $H = \frac{3}{1.28} = 2.4$ feet for the revetment.

3. Stone Sizes. The size of armor stones from the WES formula was computed using

$\gamma_r = 165$
$\gamma_w = 64.0$
$H = 7.0$ for the jetty and 2.4 for the revetment
$K_\Delta = 2.6$
$Sr = \frac{165}{64} = 2.58$
$\cot\alpha = 1.5$

from which $W_r = 3{,}680$ pounds for the jetty and 348 pounds for the revetment. Armor stone sizes of 3,500 to 4,000 pounds for the jetty and 400 to 1,000 pounds for the revetment with side slopes of 1 vertical to 1.5 horizontal are therefore considered satisfactory. Size of core stone for the jetty to make a sand tight structure and prevent loss of core through the voids of the armor stone was based on use of stone 1/10th of the weight of the armor. Since larger stones than this already exist in the jetty, it was impractical to adhere rigidly to the design criteria specifying successive reduction of stone sizes in layers under the armor. Use of core material consisting of quarry run stone of assorted sizes up to 400 pounds (1/10th of 4,000) with not less than 50 percent between 350 and 400 pounds is considered to be a satisfactory compromise for the jetty core. Successive layers under the revetment were based on reduction of 1/10th and 1/200th of the weight of the armor with a thickness of layers of not less than two stone diameters. A bedding layer under the armor of quarried stones, 40 to 100 pounds (1/10th of 400 and 1,000) and a thickness of two feet and a filter layer under the bedding of unscreened crushed or quarried stone of assorted sizes up to 4 inches in a 1-foot layer were determined to be satisfactory.

APPENDIX F

REPORT OF THE UNITED STATES FISH AND WILDLIFE SERVICE

ADDRESS ONLY THE
REGIONAL DIRECTOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
59 TEMPLE PLACE
BOSTON, MASSACHUSETTS

NORTHEAST REGION
(REGION 5)
MAINE
NEW HAMPSHIRE
NEW YORK
VERMONT
PENNSYLVANIA
MASSACHUSETTS
NEW JERSEY
RHODE ISLAND
DELAWARE
CONNECTICUT
WEST VIRGINIA

June 6, 1961

Division Engineer
New England Division
U. S. Army Corps of Engineers
424 Trapelo Road
Waltham 54, Massachusetts

Dear Sir:

Reference is made to your letter of April 6, 1961 in which you request comments from our Bureau relative to the probable effects the proposed Hills Beach, Biddeford, Maine beach erosion control improvement might have on the fish and wildlife resources. This letter constitutes our conservation and development report on the project and has been prepared in cooperation with the Maine Departments of Inland Fisheries and Game and Sea and Shore Fisheries and the Bureau of Commercial Fisheries and has their concurrence.

The plan as proposed for protection and improvement of Hills Beach would consist of widening approximately 5,400 feet of beach adjacent to and southeast of the existing Saco River south jetty to a 125-foot width by direct placement of sand fill, reconstruct 830 feet of the inshore end of the jetty and construct a 300-foot groin in the vicinity of the Basket Island tombolo. Possible areas from which sand fill could be obtained include "The Pool" behind the beach, offshore in front of the beach, and the mouth of the Saco River. The fill would be obtained by hydraulic dredging. It is understood that if dredging is accomplished in The Pool it would be done to a depth of about 6 feet below mean low water over an area of about 10 acres. It is also understood that a portion of The Pool inside the Wood Island Harbor inlet was dredged in recent years.

There are important wildlife values associated with this project. The large triangular area formed by the Saco River south jetty, Hills Beach and Stage Island is an important waterfowl area. The shoals and flats provide excellent feeding habitat for waterfowl, somewhat protected by the jetty, beach and to some degree by the islands. Waterfowl are frequently observed feeding in the lee of the jetty and the islands. Significant use is made of this area for winter feeding purposes. Particularly heavy use is made of this area during migration periods. Waterfowl are hunted from the jetty and islands.

The large enclosed area immediately behind Hills Beach, known as "The Pool", also receives some waterfowl use but this is not a significantly important area. The mouth of the Saco River is not important from a waterfowl standpoint.

Soft shell clams exist throughout most of the area of possible dredging. Within The Pool the greatest concentration is found in the southern portion, an area not expected to be affected by the proposed project. Because of the heavily polluted condition of this entire area clamming has been prohibited for about 15 years.

The actual placement of fill on the beach, groin construction, and reconstruction of 830 feet of the inshore end of the existing south jetty would have no significant effect on the fish and wildlife resources. However, the area ultimately selected as a source of beach fill is of concern to this Bureau. The area lying between Hills Beach and the south jetty is, as has been pointed out, a significantly important waterfowl area from which we would object to spoil being taken. The Pool and the mouth of the Saco River are areas of less concern to us and from which we would have no objections to your obtaining fill for the beach erosion project.

In view of the above it is recommended –

1. That no beach fill be obtained from the off-beach area lying between Hills Beach and the south jetty.

2. That the mouth of the Saco River be given first consideration as a source of beach fill and that The Pool be given second consideration.

Should there be any significant changes in the plans for this project we would appreciate being notified so that a new report can be prepared.

The opportunity to report on this project is appreciated.

Sincerely yours,

E. W. Bailey, Acting
Regional Director

APPENDIX G

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF HILLS BEACH, BIDDEFORD, MAINE

INFORMATION CALLED FOR BY SENATE RESOLUTION 148, 85TH CONGRESS, ADOPTED 28 JANUARY 1958

1. Beach Erosion Problems. The study covers the shore of Hills Beach, Biddeford, Maine between the south jetty at the Saco River entrance and the entrance to The Pool at Biddeford. The problem consists of erosion and loss of the sandy beach with consequent exposure of bluffs, sea walls, shore road, cottages and residences to damages from wave attack. The beach is exposed to wave attack from the northeast and east across the Atlantic Ocean and the Gulf of Maine. The mean range of tide is 8.7 feet and the Spring range is 9.9 feet. The maximum height of tide, observed at Portland, was 4.3 feet above the plane of mean high water.

2. Improvements Considered. Plans were considered for protection of the beach as described below:

a. Widening approximately 5,400 feet of beach adjacent to and southeast of the existing Saco River south jetty to a 125-foot width by direct placement of sand fill and raising 700 feet of the inshore end of the jetty.

b. Construction of stone revetments in front of existing sea walls or bluffs as an alternative method of protection instead of the beach widening and jetty raising.

3. Conclusion and Recommendations. Due to the private ownership of the shore and the lack of public benefits as required by Public Law 826, 84th Congress, Hills Beach is not eligible for Federal assistance in the construction of protective works. It was therefore recommended that no project be adopted by the United States for the protection of Hills Beach. It was further recommended that protective measures which may be undertaken by local interests, based upon their determination

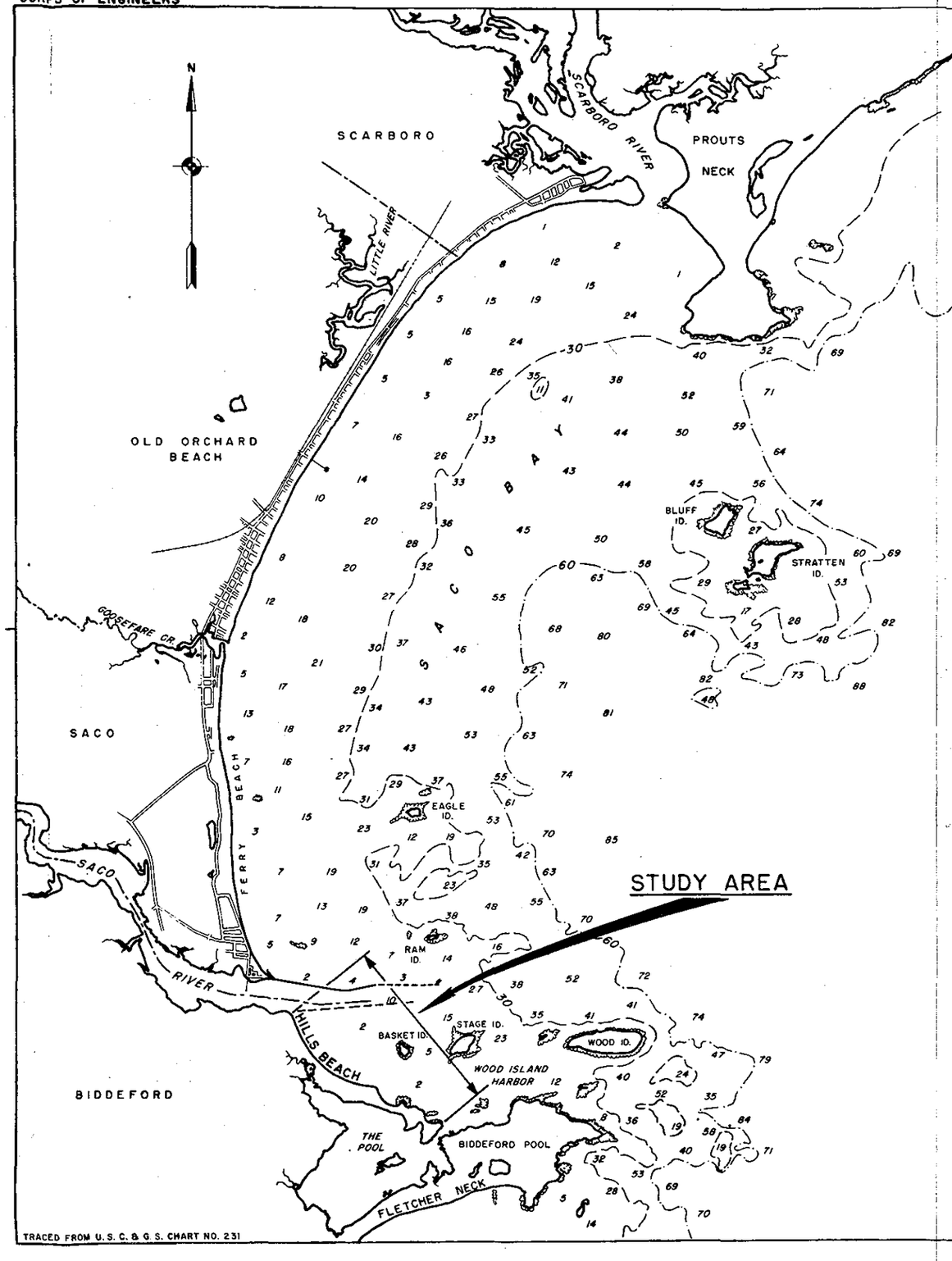
of economic justification be accomplished in accordance with plans and methods considered in the report. Estimated first costs of considered improvements, all non-Federal, are listed below:

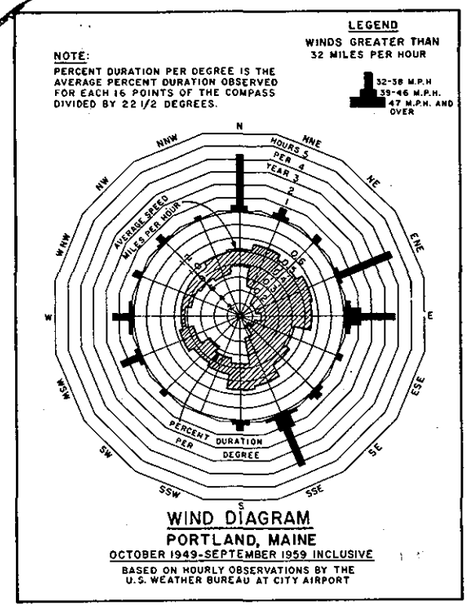
Improvement	Estimated First Cost
Beach Widening and Jetty Raising	$560,000
Alternative Protection - Stone Revetment at Seawalls	$29.00 per linear foot
Alternative Protection - Stone Revetment at Bluffs	$47.00 per linear foot

4. Discussion. The economic justification for construction of the considered projects has not been determined. Benefits were not evaluated since benefits to be derived are principally private and not of a type to make the improvements eligible for Federal aid under existing Federal policy. Changing the economic life of the projects would not change the findings of the study insofar as they pertain to eligibility for Federal aid.

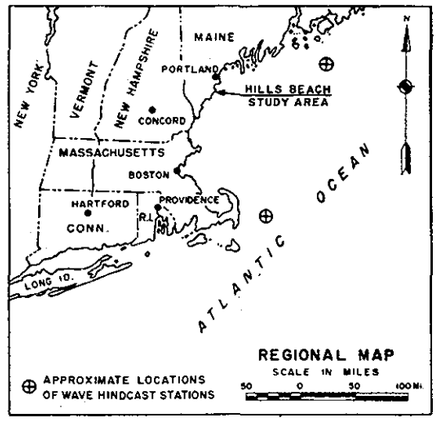
CORPS OF ENGINEERS

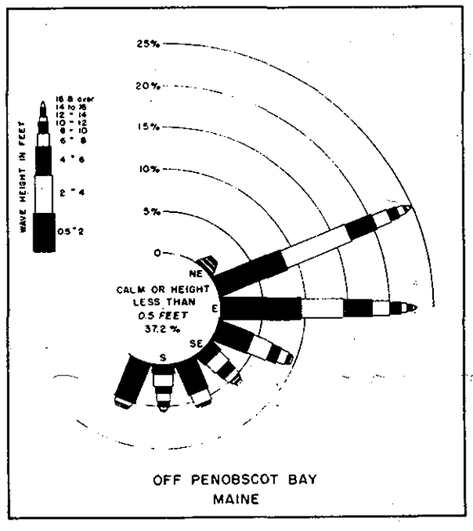
U.S. ARMY



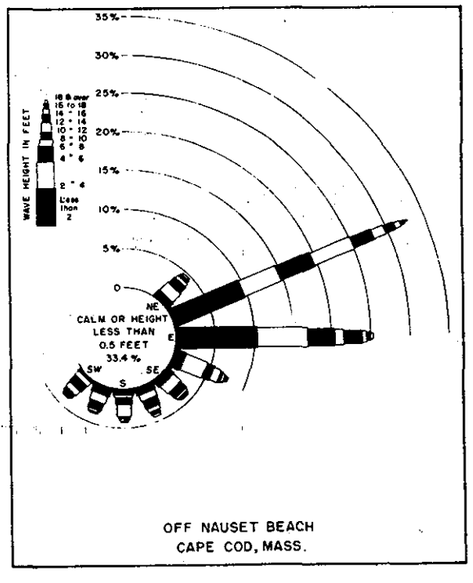


WIND DIAGRAM
PORTLAND, MAINE
OCTOBER 1949-SEPTEMBER 1959 INCLUSIVE
BASED ON HOURLY OBSERVATIONS BY THE U.S. WEATHER BUREAU AT CITY AIRPORT





OFF PENOBSCOT BAY
MAINE



OFF NAUSET BEACH
CAPE COD, MASS.

WAVE ROSES

COMPOSED OF DATA OBTAINED BY HINDCAST OF 3 YEARS OF WIND RECORDS (1948-1950), SHOWING PERCENT OF TIME WAVES OF DIFFERENT HEIGHT OCCUR FROM EACH DIRECTION. FROM BEACH EROSION BOARD TECHNICAL MEMORANDUM NO. 55.

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF
HILLS BEACH, BIDDEFORD, MAINE
LOCATION MAP

SHEET 1 OF 1 — SCALE IN FEET 2000 0 2000 4000 6000 — OCT. 1960

APPROVED
CHIEF, ENGINEERING DIVISION
SUBMITTED
CHIEF, PLANNING AND REPORTS BRANCH
CHIEF, RIVER AND HARBOR SECTION
PROJECT ENGINEER

CH. BY A.D.C.
TR. BY A.D.C.
CH. BY H.S.P.

TRANSMITTED WITH REPORT DATED: JULY 27, 1961

FILE NO. B.E. ME. 1

PLATE NO. 1

CORPS OF ENGINEERS

U. S. ARMY

CAMP ELLIS

SACO RIVER

HILLS BEACH

BULKHEADS LOCATED IN SURVEY OF 1916.

LEGEND

1934
1929
1923
1919
1916
1912
1909
1898
1892
1883
1872
1871
1844
1859

SACO RIVER ENTRANCE
MAINE
CHANGES IN SHORELINE

U.S. ENGINEER OFFICE, BOSTON, MASS., MAY 16, 1938

SCALE IN FEET

0 100 500 1000

COPIED FROM MAP FILE NO. 338 D-2-1

SACO RIVER

ROCK JETTY

ROCK JETTY

HILLS BEACH

FLETCHER NECK

Ram Is.

Stage Is.

Goose Is.

Wood Island

Lt Ho

Halfman Pt

Fletcher

23' 22' 21' 70°20'

43°28'

27'

26'

LEGEND

HIGH WATER SHORE LINE 1859 — U.S.C. & G.S.
" " " " 1871 — " "
" " " " 1913 ····· " "
" " " " 1941 — · — · — " "
" " " " 1954 ····· " "
" " " " 1960 — ● — CORPS OF ENGRS.

	6 FT.	12 FT.	18 FT.	
1859	— · —	— ·· —	— ··· —	U.S.C. & G.S.
1875	— · —	— ·· —	— ··· —	" "
1885	— · —	— ·· —	— ··· —	" "
1923	— · —	— ·· —	— ··· —	" "

NOTE:
1960 high water line added at U.S. Army Engineer Division, New England.

SACO BAY, MAINE

SHORE LINE AND OFFSHORE DEPTH CHANGES

BEACH EROSION BOARD, WASHINGTON, D.C. JUNE 1955

POLYCONIC PROJECTION DATUM NA 1927

SCALE IN FEET

0 1000 2000 3000 4000

TRANSMITTED WITH REPORT
DATED: JULY 27, 1961

FILE NO. B.E. ME. 2

PLATE NO. 2

CORPS OF ENGINEERS

U. S. ARMY

SACO RIVER

SACO BAY

SOUTH JETTY

BEACON

HILLS BEACH

ROAD

BASKET ISLAND

STAGE ISLAND

WOOD ISLAND

HARBOR

THE POOL

GOLD

BIDDEFORD

E 444,000 | E 445,000 | E 446,000 | E 447,000 | E 448,000 | E 449,000 | E 450,000

70° 22' 30" | 70° 22' 00" | 70° 21' 30"

N 228,000 | N 227,000 | N 226,000 | N 225,000 | N 224,000

43° 27' 20" | 43° 27' 00"

LIST OF PROBINGS

NUMBER	DEPTH OF WATER	ELEVATION BELOW M.L.W. DEPTH OF PROBE	PENETRATION	MATERIAL
1	2.8	12.8	10'	Sand
2	5.1	15.1	10'	"
3	8.8	18.8	10'	"
4	2.4	12.4	10'	"
5	3.1	11.1	8'	Refusal, rock

NOTES:

Depths are in feet and tenths and are are referred to the plane of Mean Low Water.

Probings taken with a 3/4" iron pipe forced down by two men and jet stream from a 1½ H.P. motorized pump.

LEGEND

Concrete wall

Timber

Stone

Riprap

NOTES:

Soundings and elevations are in feet and tenths and are referred to the plane of Mean Low Water.

Shore line is Mean High Water. Land contours are referred to the plane of Mean Sea Level.

Beach profiles from survey of Feb. 1960.

Saco Bay shoreline and shore protective structures between Saco River and the entrance to The Pool from survey of Feb. 1960. Other shoreline and topography from U.S.C.&G.S. planimetric maps of 1952-1953. Land contours from Army Map Service topographic quadrangles.

Plane coordinates are based on the Transverse Mercator Projection Maine-West Zone.

Probings shown thus ● P-2

Profiles shown thus —(2)

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF
HILLS BEACH, BIDDEFORD, MAINE
SURVEY MAP

SHEET 1 OF 1

SCALE IN FEET 200 0 200 400 600

OCT. 1960

APPROVED: John Wm. Leslie
CHIEF ENGINEERING DIVISION

SUBMITTED:
CHIEF PLANNING BRANCH

CHIEF RIVER AND HARBOR SECT.

PROJECT ENGINEER

CH BYADC

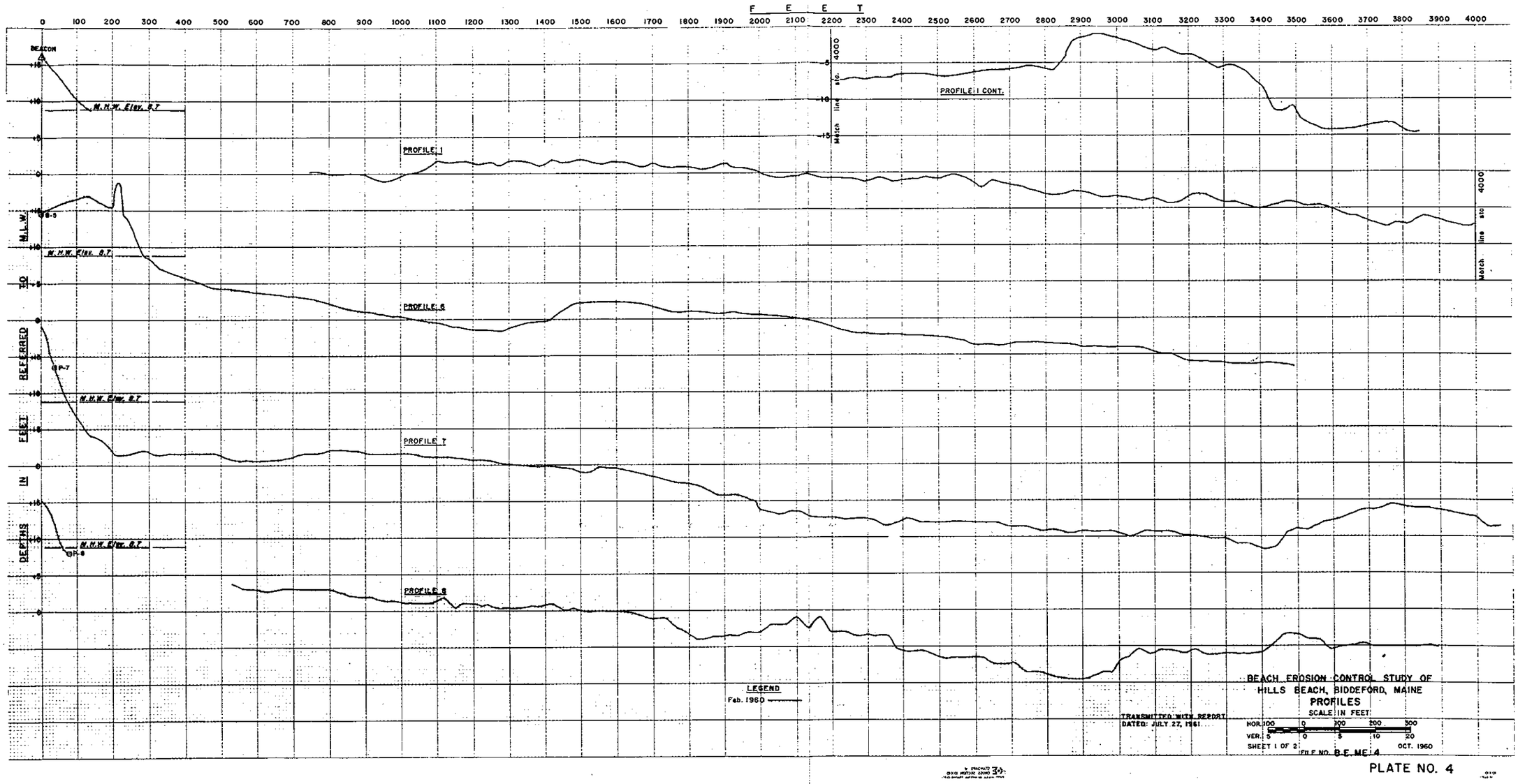
TR BYADC

CH BYMSP

TRANSMITTED WITH REPORT DATED: JULY 27, 1961

FILE NO. B.E. ME. 3

PLATE NO. 3



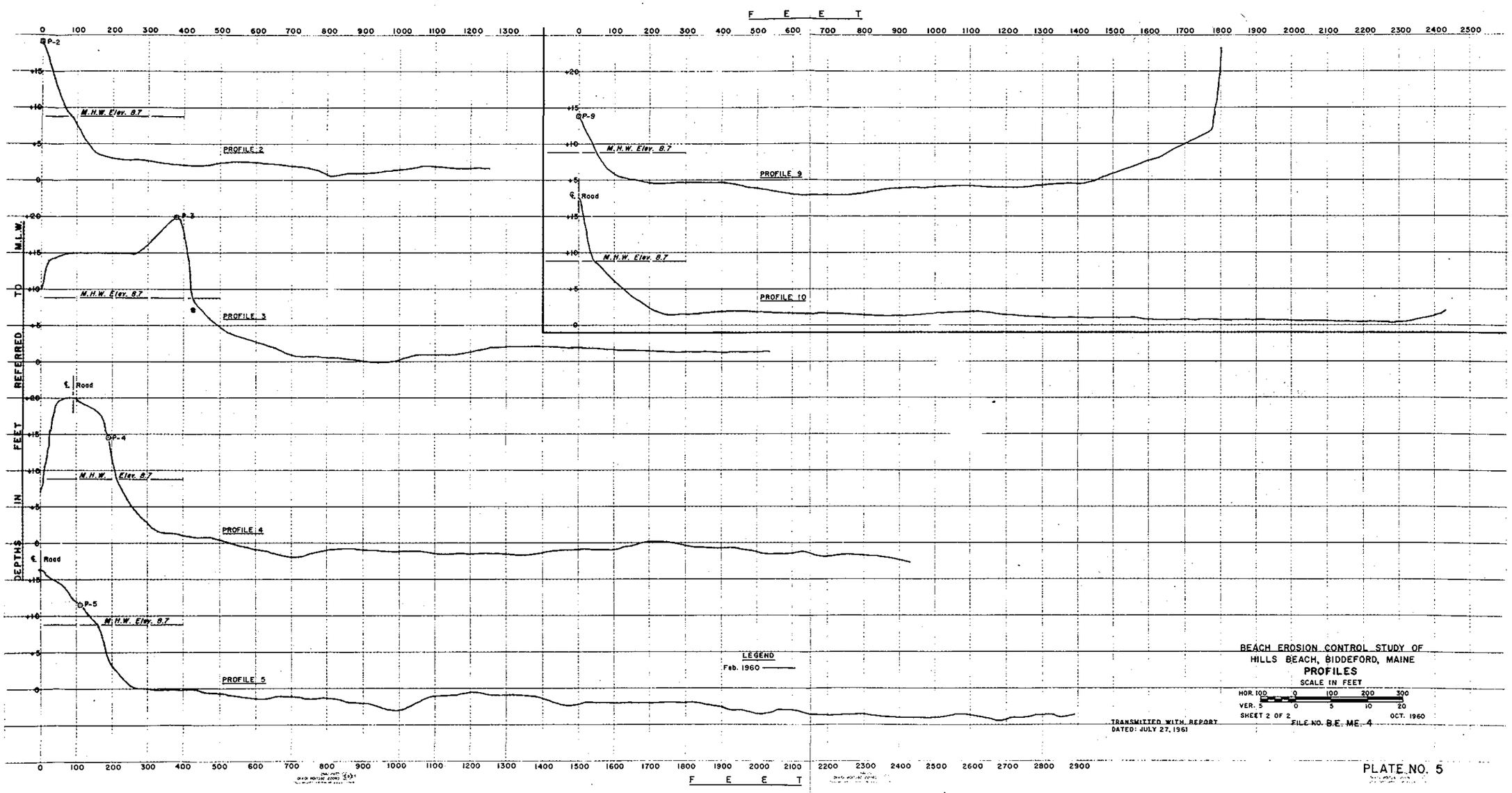
BEACH EROSION CONTROL STUDY OF
HILLS BEACH, BIDDEFORD, MAINE
PROFILES

SCALE IN FEET
HOR. 100 0 100 200 300
VER. 5 0 5 10 20

TRANSMITTED WITH REPORT
DATED: JULY 27, 1961

SHEET 1 OF 2 OCT. 1960
FILE NO. B.E. ME.4

PLATE NO. 4



BEACH EROSION CONTROL STUDY OF
HILLS BEACH, BIDDEFORD, MAINE
PROFILES
SCALE IN FEET
HOR. 100 0 100 200 300
VER. 5 0 5 10 20
SHEET 2 OF 2 OCT. 1960
FILE NO. B.E. ME. 4

TRANSMITTED WITH REPORT
DATED: JULY 27, 1961

PLATE NO. 5

CORPS OF ENGINEERS

U. S. ARMY

SACO RIVER

SACO BAY

PROPOSED RAISING OF INSHORE END OF JETTY

700'

SOUTH JETTY

BEACON

70°22'30"

E 446,000

70°22'00"

E 447,000

E 448,000

E 449,000

70°21'30"

E 450,000

N 228,000

N 227,000

43° 27' 20"

N 226,000

43° 27' 00"

N 225,000

IMPROVEMENT FOR CONSIDERATION OF LOCAL INTERESTS

WIDEN BEACH BY DIRECT PLACEMENT OF SAND FILL

RAISE INSHORE 700 FEET OF JETTY

ALTERNATIVE IMPROVEMENTS FOR CONSIDERATION OF LOCAL INTERESTS

CONSTRUCT STONE REVETMENTS ALONG SEAWALLS AND BLUFFS FOR PROTECTION OF INDIVIDUAL PROPERTIES

PROPOSED M.H.W. OF SAND FILL GENERALLY 125 FEET SEAWARD OF EXISTING PROTECTIVE STRUCTURES

125'

HILLS BEACH

ROAD

BEACH

BASKET ISLAND

STAGE ISLAND

WOOD ISLAND HARBOR

LOW SECTIONS OF SHORE ROAD CAN BE RAISED TO ACT AS A BARRIER TO LANDWARD SAND MOVEMENT

BIDDEFORD

THE POOL

FILL SLOPE
1 on 10 above M.H.W.
1 on 30 below M.H.W.

El. 15.0

M.H.W. El. 8.7

Sand Fill

Existing Bottom

TYPICAL PROFILE OF PROPOSED SAND FILL

SCALE IN FEET

HOR. 100 0 100 200 300

VER. 10 0 10 20 30

FILL SLOPE
1 on 10 above M.H.W.
1 on 30 below M.H.W.

Top width 5'
Side slopes 1 on 1.5

Layer of cap and slope stones 3500-4000 lbs., with minimum thickness of 5 feet.

Sand tight core of quarry run stone up to 400 lbs. between armor stone and existing jetty.

700'

530'

70'

100'

Proposed Jetty Raising

El. 16.0

5'

Sand Fill

M.H.W. El. 8.7

Existing Bottom

Top Existing Jetty

PROFILE OF PROPOSED JETTY RAISING AND SAND FILL

SCALE IN FEET

HOR. 100 0 100 200 300

VER. 10 0 10 20 30

Varies

4'

6'

1.5 / 1

Armor Stone

Existing Wall

Existing Beach

M.H.W. El. 8.7

2' Bedding Layer

1' Filter Layer

SEAWALL PROTECTION

STONE SIZES (Both sections)

Armor Stone: Dumped quarried stone 400 to 1000 lbs.

Bedding Layer: Quarried stone layer, 40 to 100 lbs.

Filter Layer: Quarried or crushed, unscreened stone layer with assorted stone sizes up to 4"

Varies

7.20'

6'

Armor Stone, 4'

1.5 / 1

2'

Existing Bluff

Grade bluff to 1 on 1.5 slope

M.H.W. El. 8.7

2' Bedding Layer

1' Filter Layer

BLUFF PROTECTION

TYPICAL SECTIONS OF STONE REVETMENT

SCALE IN FEET

HOR. 10 0 10 20 30

VER. 5 0 5 10 15

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS, WALTHAM, MASS.

BEACH EROSION CONTROL STUDY OF HILLS BEACH, BIDDEFORD, MAINE

PLANS OF PROTECTION

SHEET 1 OF 1 — MAY 1961

SCALE IN FEET

200 0 200 400 600

APPROVED: John Wm. Leslie, CHIEF, ENGINEERING DIVISION

SUBMITTED: CHIEF, PLANNING AND REPORTS BRANCH

CHIEF, RIVER AND HARBOR SECTION

PROJECT ENGINEER

DR BY A.D.C.

TR BY A.D.C.

CH BY H.S.P.

TRANSMITTED WITH REPORT DATED: JULY 27, 1961

FILE NO. B.E. ME. 5

PLATE NO. 6